Unit Test Analysis: Quantities in Chemical Reactions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Test Question # | Question Type | Coded Ministry Expectations | Achievement Chart Category | | | |
| Knowledge and Understanding | Thinking and Investigation | Communication | Application |
| 1 | Multiple choice | D3.2 | √ |  |  |  |
| 2 |  | D3.2 | √ |  |  |  |
| 3 |  | D3.2 | √ |  |  |  |
| 4 |  | D3.2 |  |  |  | √ |
| 5 |  | D3.2 |  |  |  | √ |
| 6 |  | D3.3 | √ |  |  |  |
| 7 |  | D2.3, D2.5 |  |  |  | √ |
| 8 |  | D2.2 |  | √ |  |  |
| 9 |  | D2.3, D2.5 |  | √ |  |  |
| 10 |  | D2.3, D3.2 | √ |  |  |  |
| 11 | Short Answer | D1.1, D2.1, D3.2 | √ |  | √ |  |
| 12 |  | D2.1, D3.3 |  |  | √ | √ |
| 13 |  | D3.7 |  |  | √ | √ |
| 14 |  | D2.3, D3.2 | √ |  | √ | √ |
| 15 | Long Answer | A1.11, D2.3, D2.4 |  | √ | √ | √ |
| 16 |  | D2.1, D2.3, D2.5 | √ | √ | √ | √ |
| 17 |  | D1.1, D2.5, D2.6, D3.4 | √ | √ | √ |  |

**Ministry Expectations**

**A1.11** Communicate ideas, plans, procedures, results, and conclusions in writing, using appropriate language and a variety of formats (e.g. data tables, models)

**D1.1** Analyse processes in the home, the workplace, and the environmental sector that involve the use of chemical quantities and calculations

**D2.1** Use appropriate terminology related to quantities in chemical reactions

**D2.3** Solve problems related to quantities in chemical reactions by performing calculations involving quantities in moles, number of particles, and atomic mass

**D2.4** Determine the empirical formulae and molecular formulae of various chemical compounds, given molar masses and percentage composition or mass data

**D2.5** Calculate the corresponding mass, or quantity in moles or molecules, for any given reactant or product in a balanced chemical equation as well as for any other reactant or product in the chemical reaction

**D2.6** Solve problems related to quantities in chemical reactions by performing calculations involving percentage yield and limiting reagents

**D3.2** Describe the relationships between Avogadro’s number, the mole concept, and the molar mass of any given substance

**D3.3** Explain the relationship between the empirical formula and the molecular formula of a chemical compound

**D3.4** Explain the quantitative relationships expressed in a balanced chemical equation, using appropriate units of measure

SCH3U Chemistry Test:

QUANTITIES IN CHEMICAL REACTIONS

**Achievement Chart Categories**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Knowledge/**  **Understanding** | **Thinking/**  **Investigating** | **Application** | **Communication** | **TOTAL** |
| /13 | /17 | /11 | /16 | /57 |

**‘Mole’tiple Choice [10]**

Clearly circle the best answer for each of the following questions (10 min)

1. The mole is used because: [K/U, 1]

|  |  |  |  |
| --- | --- | --- | --- |
| a. | Scientists like to make things more complicated for the masses | c. | The periodic table is unreliable for such information |
| b. | The atom is too small of a unit to use | d. | Atoms do not weigh enough to count |

1. Which of the following statements is false concerning the value of one mole? [K/U, 1]

|  |  |  |  |
| --- | --- | --- | --- |
| a. | It equals ~32 g of sulfur | c. | It equals 6.022 x 1023 atoms in NaCl |
| b. | It represents 6.022 x 1023 molecules | d. | It is referred to as the chemist’s dozen |

1. Avogadro’s number has the same value as the number of: [K/U, 1]

|  |  |  |  |
| --- | --- | --- | --- |
| a. | Molecules in 1 mol of solid iodine | c. | Atoms in 1 mol of solid KBr |
| b. | Atoms in 1 mole of chlorine gas | d. | Protons in 1 mol of helium gas |

1. What is the approximate molar mass, in g/mol, of MgSO4•7H2O? [A, 1]

|  |  |  |  |
| --- | --- | --- | --- |
| a. | 120 | c. | 138 |
| b. | 130 | d. | 246 |

1. Which sample has the greatest mass? [A, 1]

|  |  |  |  |
| --- | --- | --- | --- |
| a. | 6.0 x 1025atoms of hydrogen | c. | 1.2 x 1024 atoms of silver |
| b. | 5.0 mol of neon atoms | d. | 1.7 x102 g of iron |

1. Which is both an empirical and a molecular formula? [K/U, 1]

|  |  |  |  |
| --- | --- | --- | --- |
| a. | C5H12 | c. | C4H8 |
| b. | C5H10 | d. | C4H10 |

1. In oxygen poor environments, such as stagnant swamps, decay is promoted by anaerobic bacteria. [A, 1]

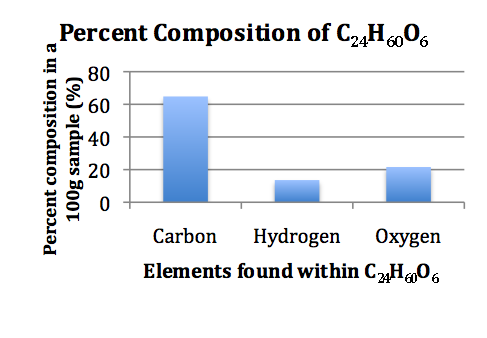
C6H12O6*(s)*  3CO2*(g)* + 3CH4*(g)*



If 15.0 kg of glucose is broken down, the mass of methane produced is:

|  |  |  |  |
| --- | --- | --- | --- |
| a. | 4.01 mg | c. | 1.34 mg |
| b. | 4.01 kg | d. | 1.34 kg |

1. The following bar chart shows the percentage composition of an organic compound found within a 100g sample. After observing and analyzing the bar chart, determine which of the following statements would be **true** about the compound. [T/I, 1]

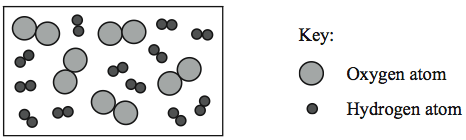


|  |  |  |  |
| --- | --- | --- | --- |
| a. | (% carbon) + (% Hydrogen) + (% Oxygen) = 100% | c. | (% carbon + % hydrogen + % oxygen) / 100g = 100% |
| b. | (% carbon/100g) + (% hydrogen/100g) + (% oxygen/100g) = 100% | d. | 100g (% carbon + % hydrogen + % oxygen) = 100% |

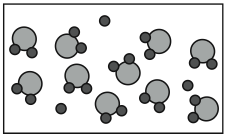
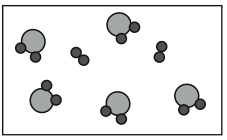
1. 12 molecules of hydrogen gas, H2(g), and 5 molecules of oxygen gas, O2(g), were mixed together under conditions which allowed the reaction to go to completion, according to the following equation. [T/I, 1]

2H2 (g) + O2(g) → 2H2O(g)

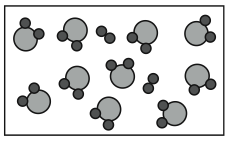
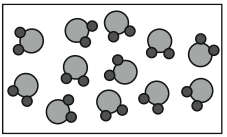
The following diagram represents the mixture of reactants.



Which diagram represents the reaction mixture when the reaction is complete?



a. c.



b. d.

1. There are more carbon atoms in a 3.00 g sample of C2H4 than in 6.00 g of C3H8. [K/U, 1]

|  |  |  |  |
| --- | --- | --- | --- |
| a. | True | b. | False |

**Short Answer [10]**

1. When cancer patients begin chemotherapy treatment, doctors must optimize the amount of drug that each patient receives. If too little is given, there may not be enough drug to kill all of the cancer cells, or the cancer cells may become resistant. If too much is given, the drug may damage non-cancer cells leading to extreme side effects (nausea, fatigue, etc), organ damage or even death. Explain why doctors would need to use the mole concept when treating patients with cancer. [K/U, 1; C, 1]

To make decisions about medication dosage for cancer patients, doctors must be quantitative, not qualitative. To be quantitative in chemistry, scientists rely on mole units. To measure using mass is not enough, because scientists and medical professions must be able to predict the effects of this drug on chemical reactions that take place within the body.

**Answer either Question 12 or 13:**

1. You are a lawyer representing a client charged with possession of a controlled substance. The prosecutor introduces as forensic evidence the empirical formula of the substance found in your client’s possession. How would you argue the evidence for the defense? [A, 1; C, 1]

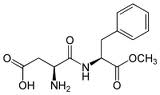
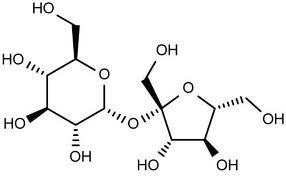
The empirical formula does not tell you *exactly* what the controlled substance is, therefore it is not conclusive evidence that the client had possession of a controlled substance. If however, the prosecutor submitted evidence of the empirical formula and the molar mass of the substance, the molecular formula could be calculated and the court would be able to tell if the substance was in fact illicit.

1. The label on a box of baking soda (sodium bicarbonate) claims that there are 145 mg of sodium per 0.500 g of baking soda. Comment on the validity of the claim? [A, 1; C, 1]

Molar Mass of NaHCO3 = 23+1+12+16(3) = 84 g/mol

% of Na in NaHCO3 = 23/84 x 100% = 27%

1. The Nutri-Sweet artificial sweetener known as aspartame, C14H18N2O5, is used to sweeten diet foods, coffee and soft drinks instead of sucrose, C12H22O11.
2. Explain how it is possible for one mole of aspartame to weigh less than 1 mole of sucrose even though they both contain 6.022 x 1023 molecules. [A, 1; C ,1]



**1 mole of aspartame 1 mole of sucrose**

Molar mass of aspartame = 12(14) + 1(18) + 14(2) + 16(5) = 294 g/mol.

Molar mass of sucrose = 12(12) + 1(22) + 16(11) = 342 g/mol.

The mass of one molecule of aspartame is less then the mass of one molecule of sucrose. Therefore even though there are equal numbers of particles, the mass of 1 mole of aspartame is less because aspartame molecules are lighter.

1. Headaches are a common symptom reported by people who consume large quantities of aspartame. Health Canada recommends that no more than 2.7g of aspartame should be consumed daily. If there are 0.00061 mol of aspartame per can of diet cola, what is the maximum number of cans an adult can consume before going over Health Canada’s limit? [C, 1; A, 2; K/U, 1]

Molar mass C14H18N2O5 = 14(12) + 18(1.01) + 2(14.0) + 5(16.0) = 294g/mol

0.00061 mol x 294g = 0.180 g aspartame/can

mol

2.7g/0.180g = 15 cans of soda

Therefore 15 cans can be consumed before reaching Health Canada’s limits.

**Long Answer [37]**

1. You are looking in your cupboard for sucrose (C12H22O11) to make cupcakes. You find an unlabeled jar that contains a white powder. Like in chemistry class, you immediately take caution and send a sample of the substance to an analytical chemistry lab to determine its composition. The results of the test tell you that it is composed of 32% carbon, 4% hydrogen, and 64% oxygen, and has a molar mass of 150.1 g/mol.
2. Given the information above, explain why this substance is not sucrose. Show your work. [A, 1; C, 1]

Msucrose = MC + MH + MO

= 12(12.01 g/mol) + 22(1.01 g/mol) + 11(16 g/mol)

= 144.12 g/mol + 222.2 g/mol + 176 g/mol

= 542.32 g/mol

Molar mass of unknown (150.1g/mol) is much less than molar mass of sucrose (542.32g/mol)

1. Being the avid chemist that you are, you are determined to solve the mystery substance. Given the information above, find the **empirical formula** of the unknown compound. Organize your work in a table. [T/I, 4; C, 1]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Element** | **Percent composition (%)** | **Mass in 100g sample (g)** | **Molar mass (g/mol)** | **Moles**  **(mol)** | **Molar**  **Ratio** |
| C | 32 | 32 | 12.01 | 32/12.01  = 2.664 | 2.664/2.664  = 1 |
| H | 4 | 4 | 1.01 | 4/1.01  = 3.960 | 3.960/2.664  = 1.49 |
| O | 64 | 64 | 16.00 | 64/16.00  = 4 | 4/2.664  = 1.50 |

Therefore, the empirical formula is: C1x2H1.49x2O1.50x2 = C2H3O3

1. To complete your investigation, determine the **molecular formula** of this mystery compound. [T/I, 3; C, 1]

M(C2H3O3) = MC + MH + MO

= 2(12.01 g/mol) + 3(1.01 g/mol) + 3(16 g/mol)

= 24.02 g/mol + 3.03 g/mol + 48 g/mol

= 75.05 g/mol

*x* = molar mass of compound/molar mass of empirical formula

= 150 g/mol / 75.05 g/mol

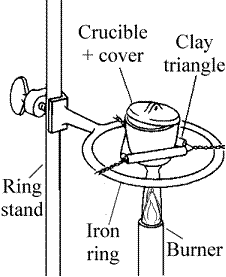
= 1.999 = 2

Therefore, the molecular formula of the unknown compound is: C2*x*H3*x*O3*x* = C4H6O6

1. Many of Ontario’s lakes and fresh water systems have been contaminated by pollution-induced acid rain. To counter these effects, ecologists are attempting to neutralize fresh water systems by adding CaO(s) to the water - when in water, CaO(s) is converted to the base Ca(OH)2(aq). To synthesize CaO(s), chemists heat limestone, CaCO3(s), to produce CO2(g) and CaO(s).
2. Write a balanced chemical equation for the production of CaO(s) from limestone [T/I, 1].

CaCO3(s) + heat → CaO(s) + CO2(g)

1. If you were the chemist responsible for synthesizing CaO(s), draw a scientific diagram of the laboratory apparatus you would use in the lab. Be sure to label your diagram appropriately. [C, 5]



1. As the reaction between CaO(s) and water is quite vigorous, CaO(s) can cause severe irritation when inhaled or placed in contact with moist skin or eyes. Suggest TWO appropriate safety precautions, scientists should take when working with CaO(s). [K/U, 2]

**Precaution1:** Wear gloves, lab coat, and inhalation mask

**Precaution 2:** Store CaO(s) in a dry place away from moisture (E.g. in a desiccator)

1. Neutralization of Lake Weslemkoon near Bancroft, ON requires 10 kg of CaO. If you had 8 kg of CaCO3 available in your lab, would you have enough starting material to completely neutralize the lake? Show all of your work. [A, 3; C, 1]

8 kg CaCO3 x 1000g x mol CaCO3 x 1 mol CaO x 56 g x 1 kg

1 kg 100 g 1 mol CaCO3 mol CaO 1000g

= 4.48 kg CaO

Only 4.5 kg of CaO(s) would be produced, therefore there would NOT be enough CaCO3 to completely neutralize the lake.

1. The neutralization of lakes illustrates how important it is for scientists to make predictions using the mole. Describe ONE other example of mole calculations having practical implications on society. [C, 1]

Answers will vary. Determination of recommended dose for medications/drug treatments.

1. Your friend, Farhana, is having trouble understanding the concept of a limiting reagent. She constantly mutters at her desk, “It’s like it’s total gibberish!” She has asked you for help visualizing and applying these concepts.
2. Describe an “every day” analogy you might use to help Farhana distinguish between an excess reagent and a limiting reagent. [K/U, 3; C, 1]

E.g. making smores 🡪 need 2 crackers, 1 marshmallow and 4 chocolates

you are given 20 chocolates, 4 crackers and 20 marshmallows. You are only able to make 2 smores since the crackers are the limiting reagent. The marshmallows and chocolate will be in excess.

1. It is a good thing that you taught Farhana about limiting reagents because she has been put in charge of salting all of the sidewalks this winter. The salt that she has decided to use is calcium chloride, CaCl2. To generate this salt in the lab, Farhana has obtained 6g of calcium and 9g of chloride that will be reacted together as shown:

Ca (s) + Cl2 (g) 🡪 CaCl2 (s)

Farhana has tentatively decided that Cl2 is the limiting reagent. In the space provided, determine if she is right. Make sure to show all of your work. [T/I, 4]

1. Balance equation

Ca (s) + Cl2 (g) 🡪 CaCl2 (s)

1. Find moles of each reactant:

(Ca): moles of Ca = 6g/(40g/mol) = 0.15mol

(Cl2): moles of Cl2 = 9g/(70.9g/mol) = 0.12mol

1. Divide moles by coefficients:

(Ca): 0.15mol/1 = 0.15mol

(Cl2): 0.12mol/1 = 0.12mol

Therefore Cl2 is the limiting reagent

1. Determine how much of the product CaCl2 would be produced. [T/I, 2]

use molar ratio:

(mole of Cl2/coefficient) x (mole of CaCl2/coefficient)

= (0.12mol)/1 x (x mol of Cacl2)/1

= 0.12mol of CaCl2

Use molar mass to find amount of CaCl2 produced

Mass of CaCl2 = 0.12mol x 110.9g/mol

= 13.3g

1. When Farhana carried out this experiment in the lab her percentage yield was found to be 22%. How much CaCl2 did Farhana end up obtaining? [T/I, 1]

Percentage yield = (actual yield/theoretical yield) x 100%

Actual yield = (percentage yield x theoretical yield) / 100%

= (22% x 13.3g) / 100%

= 2.92g

1. Give 2 reasons why Farhana’s percentage yield was not closer to 100%. [C, 1; K/U 1]

1. competing reaction (the reverse reaction is occurring at the same time or the product begins to react with the reactant to make something new)

2. experimental design and technique e.g. some of the product getting left behind on filter paper in a filtration experiment.

3. impure reactants